Effects of Time Limits and Sleep Deprivation on Semantic Interpretation

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Abstract

Time Limit and Sleep Deprivation may affect semantic interpretation during reading comprehension which can negatively influence test performance. Fifty-one sleep deprived and not sleep deprived adult students read passages with and without time limits. The number of correct responses to the probed recall task and the detail shown on the free recall task measured semantic interpretation among participants. Inconsistent with predictions, subjects who read the passages with Time Limit and without Time Limit scored comparably on the probed and free recall tasks. Sleep deprived participants comprehended less during the probed recall task compared to non sleep deprived subjects, and comparable scores were found on the free recall task. The interaction of Time Limit and Sleep Deprivation was not statistically significant among participants. The results of this study confirmed the negative effects of sleep deprivation on semantic interpretation and some effect was noted when the two factors interacted. Further research will be needed to investigate the interaction of Time Limit and Sleep Deprivation on semantic interpretation.
Effect of Time Limit and Sleep Deprivation on Semantic Interpretation

A lack of sleep affects school performance on a number of levels, including mathematical performance and reading comprehension skills (Campos-Morales, Valencia-Flores, Castaño-Meneses, Castañeda-Figueiras, and Martínez-Guerrero, 2005). A sleep-deprived individual does not perform well on reading comprehension tasks because of their inability to interpret the text they read. Although sleep deprived individuals retain the ability to memorize facts, they are unable to use these facts in a constructive way (National Sleep Foundation, 2007).

Today’s students are experiencing a decline in sleep compared to the students of decades past. Sixty percent of children under the age of 18 experienced fatigue and sleepiness during the school day, with an additional 15% of children reporting episodes of sleep during their classes (National Sleep Foundation, 1999). The National Assessment of Educational Progress (NAEP) reports no significant improvement in reading and mathematic proficiency scores among 9- and 13-year-olds since 1973 and a steady decline in average Scholastic Achievement Test (SAT) scores in verbal and mathematical proficiency among 17-year-olds since 1967 (U.S. Department of Education, 1995; 1996). The lack of sleep experienced by students is a major factor in the lack of educational progress in America (Mitru, Millrood, and Mateika, 2002). This problem of sleep deprivation among students is not limited to grade school and high school students. Among college populations, short sleepers (individuals who sleep fewer than 6 hours a day) report significantly lower grade point averages than long sleepers (individuals who sleep more than 9 hours a day) (Kelly, Kelly, and Clanton, 2001).
Time limits affect performance on tests. Most achievement tests are administered with time limits that are insufficient for students to complete them. These time limits result in low motivation for students who feel pressured to finish tests, thus resulting in poor performance (Hill, 1980). The time limits on tests also force students to focus on completing the test at a certain speed, requiring rapid reading and a decline in reading comprehension (Preston & Botel, 1952).

Little is known about how these two factors interact with one another in relation to reading comprehension skills, yet both of these problems exist on all levels of education. Research into this issue will have a large effect on student behaviors as well as teaching practical skills on how to deal with these two factors. The interaction between Time Limit and Sleep Deprivation on reading comprehension tasks is one worth considerable investigation.

Reading Comprehension and Semantic Interpretation

Reading comprehension is a set of cognitive mechanisms that enable readers to transform text into information that the brain is able to recognize. (Zwaan & Singer, 2003). Carpenter and Daneman (1983) provide a general model of reading comprehension that consists of three stages: pattern recognition, retrieval of meaning of word, and knowledge integration.

The first stage, pattern recognition, describes how letters as parts of words or words as parts of sentences are more likely to be detected than as letters or words alone (Katzir et. al, 2006). An increase in pattern recognition skills can decrease the amount of cognitive capacity used during reading comprehension, allowing for other processes to occur (Chabot, Petros, McCord, 1983).
The second stage of reading comprehension, retrieval of meaning, involves choosing the most appropriate definition for a word and eliminating misleading interpretations by making helpful associations with other words (Carpenter, Miyake & Just, 1995).

Once the word is encoded, syntactic processing assists our brain in organizing the sentence with grammatical structure and the arrangement of words within the sentence. (McKoon & Ratcliff, 1998). Semantic interpretation follows as readers use logic to derive meaning from a sentence by considering the relations of the words within the context of a particular sentence. The sub-process of semantic interpretation consists of four parts: word-sense disambiguation, or the identification of a word as a particular part of speech (e.g. noun, verb); noun-phrase reference determination; case determination, or the recognition of how the words relate to one another; and syntactic disambiguation (Charniak & Goldman, 1988). Parsing further explains why a reader might choose one interpretation of a sentence over another (Carpenter, Miyake & Just, 1995).

The final stage, knowledge integration, occurs when readers use knowledge-based inferences by applying predictions based on personal knowledge and experiences. These inferences aid readers in clarifying the meaning of a word with relation to another word in a sentence (Graesser, Millis, Zwaan, 1997). The incorporation of prior knowledge and the use of inferences within the text build on semantic interpretation and allow for the most complete understanding of a sentence (McKoon & Ratcliff, 1998).

Time Limit and Semantic Interpretation

Little research exists on the main effect of Time Limit on Semantic Interpretation; however, research indicates certain effects on reading comprehension. School districts
and universities utilize standardized testing, yet these tests focus on reading comprehension within a time limit rather than testing knowledge and reading speed individually. Standardized reading tests are used to assess efficiency and accuracy among students; however, these tests often fail at measuring comprehension and focus more on reading rate. The time limits on these tests place slower readers at a disadvantage due to the strain brought on by a demand for faster reading which results in an inability to interpret the text accurately (Carver, 1992). Researchers propose that speed and comprehension be distinguished on tests that are used to measure reading comprehension (Anderson & Tinker, 1936).

Further research confirms a negative correlation between reading speed, comprehension and text difficulty among less efficient readers (Tinker, 1939). An efficient reader’s reading rate decreases as text becomes more difficult; however, they experience no deficit in comprehension. Less efficient readers continue reading at their normal pace, yet they experience a decrease in comprehension due to the increased difficulty of the text and imposed time limits. Less efficient readers experience decreases in reading comprehension scores due to less understanding of the text within the time limit (Blommers & Lindquist, 1944). Research also demonstrates how slower readers’ overall comprehension scores decreased after a time announcement due to reading and answering questions less carefully in an effort to go faster. Faster readers’ do not experience a decrease in score because their reading rate allows them to complete the test within the imposed time limit (Cook, 1957).

Slower readers are at a disadvantage when facing time limits and will score lower on reading comprehension tests because both speed and comprehension are reflected in
the results. Instructional methods must focus on the increase of reading speed for slower readers while allowing them to fully comprehend the text (Carver, 1992). In addition, standardized tests can be more effective when assessing reading comprehension by setting appropriate time limits for each section of the test according to the difficulty of the text (Flanagan, 1937).

A real-life example of the effects of Time Limit on reading comprehension examined a reading comprehension test given to fifth grade students. Students who were given extended time periods scored higher compared to other students who had to finish within the standard time period (Wasson, 1969). Research among third and fourth graders also demonstrates how time limits implemented in standardized testing force slower readers to finish tests inaccurately, resulting in an inaccurate evaluation of reading comprehension skills (Hill, 1980).

Researchers examined the Iowa Silent Reading Test and other standardized reading comprehension tests given to college students under time limits. These tests do not accurately assess reading comprehension because slower readers who comprehend the given texts still receive lower test scores due to added pressure brought on by time limits. These results are contrary to research that emphasizes that it does not require speed reading to be an exceptional student, as no correlation was found between reading rate and quality of understanding (Preston & Botel, 1952).

Sleep Deprivation and Semantic Interpretation:

Although there is limited research on the main effects of Sleep Deprivation on Semantic Interpretation, a great deal of research has been done on the effects of sleep deprivation on the process of reading comprehension which encompasses semantic
interpretation. Sleep Deprivation has been examined on two levels: overall sleep loss and poor sleep quality. These two distinctions of Sleep Deprivation have been studied independently of one another and produce different effects on the process of reading comprehension.

Individuals subjected to sleep loss are not necessarily unable to complete reading comprehension tasks; rather they suffer from lapses in concentration in the form of “microsleep”—small bouts of sleep during the day—which lead to poor performance on these tasks (Millman, 2005). A positive correlation exists between the level of attention required for reading comprehension tasks and the level of impairment brought on by sleep loss (Swann, Yelland, Redman, and Rajaratnam, 2005). A direct connection between sleep loss and a deficit in cognitive performance is suggested, possibly due to distractions or neurobiological impairment brought on by sleep deprivation (Meijer and van den Wittenboer, 2004).

Poor sleep quality—defined as an inability to fall asleep or remain in a sleep state—has been observed to indirectly affect reading comprehension and solving mathematical problems in students by minimizing the motivation with which these tasks are performed (Meijer and van den Wittenboer, 2004). In addition, a negative correlation also exists between reading speed and comprehension among individuals who experience poor sleep quality (Campos-Morales, Valencia-Flores, Castaño-Meneses, Castañeda-Figueiras, and Martinez-Guerrero, 2005).

As wakefulness increases, reading speed declines; however, individuals experience an increase in accuracy on reading comprehension tasks that follow. Individuals who are not sleep deprived are able to take more time reading and deriving
meaning from what they have read than their sleep deprived counterparts who read quickly as a result of a compensatory effect (Dickman, 2001).

Sleep deprivation does not always result in decreased comprehension (Webb, 1986). With older subjects, there is no marked decrease in reading speed or comprehension; nevertheless, a decline in sustained attention and concentration does exist independent of comprehension (Swann, Yelland, Redman, and Rajaratnam, 2005).

**Time Limits, Sleep Deprivation, and Semantic Interpretation**

Currently, there seems to be little research that examines the effects of Time Limits and Sleep Deprivation on semantic interpretation. However, some possible hypotheses can be drawn using research on sleep deprivation in relation to reading speed and comprehension. An increase in reading speed and a decrease in accuracy on reading comprehension tasks exists among individuals who are sleep deprived (Campos-Morales, Valencia-Flores, Castaño-Meneses, Castañeda-Figueiras, and Martínez-Guerrero, 2005; Dickman, 2001). Individuals who are not sleep deprived are able to take more time reading and deriving meaning from text, thus allowing them to perform better on comprehension tasks. This difference in reading time occurs because of the lack of concentration and attention that is suggested to be brought on by sleep deprivation (Swann, Yelland, Redman, and Rajaratnam, 2005; Webb, 1986). It is likely that with the introduction of time limits on a reading comprehension task, sleep deprived individuals will have less time to try and derive meaning from text, resulting in poorer reading comprehension. The relationship of these factors and semantic interpretation requires further explanation due to its practical importance.
There has been little research done on the specific effects of Time Limits and Sleep Deprivation on Semantic Interpretation. Research on sleep deprivation shows a decrease in performance on reading comprehension tasks due to a loss of concentration. Time limits on tests also affect the scores on reading comprehension tasks because they divert the test takers focus from the reading to the speed at which they must complete the reading. The present study involves testing sleep deprived students under time constraints on a semantic interpretation task to answer whether these two factors, when combined, produce negative effects. These results will be contrasted to students who undergo the same task without sleep deprivation or time constraint. This study will shed light on how students perform under two common factors faced by students.

Method

Participants

This study consisted of 51 male and female San Jose State University students from 18 to 26 years old. Participants were English speaking, had different majors, and varied in sleep patterns. Participants were recruited from a lower division psychology course and an upper division sociology course.

Materials

A packet containing a consent form was issued to participants before the start of the experiment (see Appendix A). The packet also contained two different experimental texts (see Appendix B and D). The texts were a narrative text and a descriptive text, both approximately 500 words, modeled after the writing style from popular science magazines. The texts were similar in reading level (11th grade) and content. The experimental texts were chosen in an effort to minimize the effects of prior knowledge,
since the topics include specific detailed descriptions that are not considered common information for the average student.

A task sheet with 7 multiple-choice questions and a section for free response was included for both experimental texts (see Appendix C and E). The questions were formulated in order to measure semantic interpretation by asking participants to recall certain events of the story in detail. Additionally, a background questionnaire which was used to determine participant’s sleep patterns and general demographic information was issued (see Appendix F).

Procedure

The experimenters distributed the packets among the students and asked that they read and sign the consent form if they wished to participate in the study. Next, students were told to turn the page and read the text in a two minute time period upon instruction. The two-minute time limit has been chosen as an appropriate time constraint since pilot participants read the text in just under two minutes. Time was measured using a hand-held stopwatch. Students were instructed not to go ahead in the packet.

Once two minutes passed, students were asked to turn to the narrative task sheet which contained a free recall section which asks for participants to summarize the texts, followed by a probed recall section with 7 questions formulated to measure semantic interpretation by asking individuals to recall certain details of the story. After an additional five minutes, researchers instructed students to stop writing. Students were told to turn to the descriptive text upon instruction. No time limit was announced for the reading of this text; however readers were given only five minutes to read the text. Once
time passed, students were asked to turn to the descriptive task sheet. Participants were
given five minutes to complete the descriptive task sheet.

Upon completion, participants were asked to complete the background
questionnaire. All packets collected from the participants were numbered individually in
order to keep track of the responses. The experiment was administered in similar
classroom settings with limited noise distracters.

*Design and Analysis*

The study was conducted using a two-by-two mixed-subjects design. The factors
being studied were Time Limit and Sleep Deprivation. The levels of the Time Limit were
measured by a two-minute time limit versus no time-limit. The Sleep Deprivation
condition was measured using the self-report from the background questionnaire. The
groups were defined as sleeping six and a half hours of average sleep per day or less
(sleep deprived) or seven and a half hours of average sleep per day or more (not sleep
deprieved). These values were used to increase the contrast between the two groups.

The dependent variable, semantic interpretation, was measured by scoring the
correct responses on the probed recall task and scoring of the free recall task. The free
recall task was scored by measuring depth of recall for the story. Participants received
points for the events they recalled, with more points given to participants who recalled
events further into the story. This collected data was used to assess the effects of Time
Limit and Sleep Deprivation on Semantic Interpretation.

*Results*

This study evaluated the effects of Time Limit and Sleep Deprivation on semantic
interpretation.
Main Effects of Time Limit

Participants who completed the probed recall task with a time limit scored comparably (M = 4.11, SD = 1.35) to participants who faced no time limit (M = 4.01, SD = 1.09). The main effect of Time Limit on the probed recall task was not statistically significant, $F(1, 77) = 1.13, p < .29$.

On the free recall task, participants who completed with a time limit scored slightly lower (M = 1.09, SD = .60) than participants who completed a similar task with no time limits (M = 1.30, SD = .82). The main effect of Time Limit on the free recall task was not statistically significant, $F(1, 77) = 1.91, p < .17$.

Main Effects of Sleep Deprivation

Participants who were sleep deprived answered fewer questions correctly on the probed recall task (M = 3.61, SD = 1.19) than participants who were not sleep deprived (M = 4.52, SD = 1.26). The main effect of Sleep Deprivation on the probed recall task was very significant, $F(2, 77) = 4.55, p < .01$.

On the free recall task, participants who were sleep deprived scored comparably (M = 1.23, SD = .74) to participants who were not sleep deprived (M = 1.15, SD = .67). The main effect of Sleep Deprivation on the free recall task was not statistically significant, $F(2, 77) = 1.22, p < .30$.

Interactions of Time Limit and Sleep Deprivation

The interaction between Time Limit and Sleep Deprivation on the probed recall task approached significance, $F(2, 77) = 2.52, p < .09$. Participants who were sleep deprived and faced time limits scored comparably on the probed recall task (M = 3.63, SD = 1.31) with participants who were sleep deprived and faced no time limits on a
similar task (M = 3.58, SD = 1.06). Participants who were not sleep deprived and faced time limits scored comparably on the questions (M = 4.59, SD = 1.39) with participants who were not sleep deprived and faced no time limit (M = 4.44, SD = 1.12).

Insert Table 1 about here

Observe in Table 1 how participants who were not sleep deprived recalled more on the probed recall task in both the timed and un-timed conditions compared to the participants who were sleep deprived.

On the free recall task, participants who were sleep deprived and faced time limits scored comparably (M = 1.17, SD = .57) to participants who were sleep deprived and faced no time limits (M = 1.29, SD = .91). Participants who were not sleep deprived and faced time limits recalled slightly fewer events (M = 1.00, SD = .62) than participants who were not sleep deprived and faced no time limits (M = 1.30, SD = .72). The interaction of Time Limit and Sleep Deprivation on the free recall task was not significant, $F(2, 77) = 1.63, p < .20$.

Discussion

This study was designed to investigate the effects of Time Limit and Sleep Deprivation on Semantic Interpretation. Previous research has demonstrated a negative correlation between sleep deprivation and lower scores on standardized tests (Campos-Morales, Valencia-Flores, Castano-Meneses, Castaneda-Figueiras, and Martinez-Guerrero, 2005). Additional research shows lower test scores among students facing a time limit during reading comprehension tests (Carver, 1992; Wasson, 1969; Hill, 1980). Previous
literature examines these two factors individually, yet there has been little research on the interaction of the two factors. This study measures semantic interpretation using a probed recall task and a free recall task on two similar texts.

The main effects of Time Limit on Semantic Interpretation in the probed recall task were not statistically significant. These results are inconsistent with previous research (Carver, 1992; Blommers & Lindquist, 1944). The unexpected outcome could be due to the difficulty of the texts used. Both the timed and untimed participants were expected to be unfamiliar with the text, making them more difficult to follow. These findings are consistent with research that shows a weaker relationship between time limits and reading comprehension once the text became more difficult (Tinker, 1939). The effects of Time Limit on Semantic Interpretation during the free recall task was also not statistically significant, which is inconsistent with previous research that shows higher test scores during tests without time limits (Preston & Botel, 1952). These unexpected results could have been influenced by the lack of responses from participants during the free recall task. A second and more reliable explanation of the unexpected outcome could have been due the scoring method used and the need to distribute error of variance more evenly in order to obtain a greater range of significant scores among participants.

The main effects of Sleep Deprivation on the probed recall task were statistically significant. These findings were congruent with previous research (Swann, Yelland, Redman, and Rajaratnam, 2005). These results may have been due to a lapse in cognitive performance caused by sleep deprivation, yet previous research does not indicate whether this is due to biological reasons or a lack of motivation (Meijer and Van den Wittenboer,
The effects of Sleep Deprivation on the free recall task were inconsistent with previous research (Dickman, 2001). The scoring method used, the limited range of scores that resulted among participants, and the lack of overall responses received from subjects can also explain these unexpected findings.

Although the interaction of Time Limit and Sleep Deprivation on Semantic Interpretation was not statistically significant, some effects were noted. These results may have been stronger if different scoring methods were applied. The text difficulty and the lack of participants' interest in the materials may have influenced these findings, too.

Time limits are very common during standardized tests and have a great influence on students’ achievement levels throughout their educational careers. Research has found a positive correlation between Time Limit and test scores, demonstrating that slower readers are put at a disadvantage in standardized test conditions regardless of their comprehension level. These results must be taken into consideration in educational institutions and other workplace settings where time limits during tests are being administered. Further research should examine the interaction between Time Limits and Sleep Deprivation by using various scoring methods and different testing conditions appropriate for a wider range of populations.
References


Appendix A: Consent form

Agreement to Participate in Research

Responsible Investigator(s): Vincent Harrington and Eva Schmeisser

Topic of the Study: Reading Comprehension

For a class on Research Methods, you have been selected to participate in a research study investigating reading comprehension among University students.

You will be asked to read two different stories and answer 16 questions regarding the details of the text. You will be given the short stories in the beginning of the study and provided with writing materials.

There is no anticipated emotional or physical risk foreseen in this study.

No information that could identify you will be included in any reports of this study. This study is strictly performed voluntarily and with no compensation given.

Questions about this research may be addressed to Eva Schmeisser or Vincent Harrington, evas321@hotmail.com or maddspeed800@yahoo.com. Complaints about the research subjects’ rights, or about research-related injury may be presented to Prof. M. L. Dillinger, Department of Psychology, San Jose State University [mike.dillinger@sjsu.edu].

Your consent is being given voluntarily. You may refuse to participate in the entire study or in any part of the study. No service of any kind, to which you are otherwise entitled, will be lost or jeopardized if you choose to “not participate” in the study. If you decide to participate in the study, you are free to withdraw at any time without any negative effect on your relations with any participating institutions or agencies. At the time that you sign this consent form, you will receive a copy of it for your records, signed and dated by the investigator.

Your signature on this document indicated agreement to participate in the study.

The signature of a researcher on this document indicates agreement to include the above named subject in the research and attestation that the subject has been fully informed of his or her rights.

Participants Signature     Date

________________________________________________________________

Researcher’s Signature     Date

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Researcher’s Signature     Date

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Appendix B: Experimental Text #1 (Narrative)

I have a friend named Alex who is a nuclear physicist, but he works in a public hospital instead of at some big university’s reactor. He spends a lot of his time shooting protons at glucose and other things. Alex makes several different isotopes with the old cyclotron which is in his lab, and he often helps one of the computer programmers who works in the hospital’s brain scanning center. Yesterday I visited Alex at the hospital.

When I found the right office, it was already 10 o’clock. Alex was reading a collection of technical articles, but he put his book on a nearby shelf when I arrived and he showed me all around the lab. He turned on the small cyclotron which was in one corner and made some fluorine isotope to demonstrate how simply it worked. The small machine made noises while Alex explained what it was doing. Afterwards, Alex made some terrible coffee. We talked about the local news for a little while, until a staff doctor asked for some carbon-eleven glucose in a hurry. He said he would call as soon as he was ready for it. Then he prepared the next patient for her scan. Alex explained that since the glucose isotope was only hot (or radioactive) for about a half an hour, he could just set up what was in the lab. He would only start to make the isotope itself when the doctor called again. Not long after Alex was all ready, the doctor called back to confirm his previous request and Alex began to prepare his magic potion right away. When he had finished it, he checked whether it was hot (or radioactive) enough for the scanner. Then we ran up to the scanner room on the third floor, with the solution in a lead bucket.

The scanner was a big aluminum ring with millions of wires connecting it to a big computer in the next room. The patient was waiting nervously for an injection on a long table, with her head inside the ring. As we walked back down the stairs together, Alex explained that scanners detect gamma rays coming from inside the patient’s brain. I didn’t really understand very much of what he was talking about. It sounded really crazy to me.

After lunch, Alex checked in at the lab. Then we visited his friend Yoshio who ran the brain scanner’s computer system. Even before he greeted us, Yoshio pointed at the two TV screens on a large desk and then asked which image was clearer. Yoshio was working on a new program to make the images sharper. Then he pointed at another screen with the same brain image, but it had two handles connected to it, like a video game. He suggested how we should play around with the handles, and when we moved them, the image changed in color and brightness. Yoshio explained that it was better for the doctors to manipulate the color and brightness of the important parts of the image.

The telephone rang, interrupting him. The call was for Alex. He had to go back to the lab, and it was time I left, too. We thanked Yoshio for his explanation of the new program, and walked to the main entrance together. Then Alex went to make some other kind of isotope and I went to the bank to pay some bills. It was a very interesting visit.
Appendix C: Questionnaire for Narrative Experimental Text #1

A. Summary:

*Please summarize the events from the reading:*

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PLEASE TURN PAPER OVER AND ANSWER THE MULTIPLE CHOICE QUESTIONS

B. Questions:

1. Where does Alex the nuclear physicist work?

2. What did Alex make to demonstrate how the cyclotron worked?

3. Where was the staff doctor who requested the solution working?
   a. The scanner room       b. The lab       c. The emergency room

4. What does the scanner detect?
   a. Photons       b. Gamma Rays       c. Aluminum ions

5. What was Yoshio doing when the narrator visited him?
   a. Playing a video game       b. Eating lunch       c. Working on a program

6. What did playing around with the handles do to the image?
   a. Enlarge the image       b. Enhance the color and brightness       c. Distort the color and brightness

7. Who went to the bank at the end of the story?
   a. Yoshio       b. Alex       c. The narrator
Sometime in August 2011, a boxy space probe called Dawn will settle into orbit around one of the most underrated and overlooked objects in the solar system, a giant oblong asteroid named Vesta. After lingering for almost 10 months of study, Dawn will depart for Ceres, the biggest asteroid of all. Ceres is so large that it was recently promoted to the rank of dwarf asteroid, putting it on a par with Pluto and highlighting its status as a key planetary missing link.

Vesta and Ceres are the big enchiladas of the asteroid belt, a loose collection of rubble left over from the earliest days of the solar system. They are interesting because they’re like time capsules. “These two bodies are building blocks,” says Chris Russell, the principal investigator for the Dawn mission. It was asteroids like these that “came together to make the rest of the planets. It might have taken millions of Vesta and Cereses to make Earth. We want to understand how the building blocks were different from one another and how they came together to build the planets. Vesta and Ceres represent an important stage in the history of the solar system.”

Vesta and Ceres, along with the rest of the material in the asteroid belt, would have coalesced into a planet too, were it not for Jupiter’s powerfully disruptive gravity. Ceres is 585 miles wide and contains more than a quarter of all the mass in the asteroid belt. It was the first asteroid discovered, spotted by Italian astronomer Giuseppe Piazzi in 1801. Vesta, the second-largest asteroid, was discovered six years later. For a few years, both were regarded as bona fide planets, but scientists soon discovered many more small bodies in similar orbits. In the mid-1800s these objects were reclassified as “asteroids” and largely dismissed as bit players. It has taken a century and a half to shift that view.

Although Vesta is just under one-third the mass of Ceres, in some ways we know it much more intimately. Vesta’s composition closely matches that of a group of common meteorites that have been found on Earth, called HED meteorites; these are literally chips off Vesta’s block. Blurry but tantalizing images from the Hubble Space Telescope suggest where those space rocks came from: A massive crater dominates Vesta’s southern hemisphere, testifying to a powerful collision that gouged out nearly 1 percent of its volume a billion years ago. From studies of the HED meteorites and from measurements of light reflected off the asteroid’s surface, scientists have concluded that Vesta has a very planetlike nickel-iron core. And its surface is basaltic—largely formed by lava flows from below.

Ceres, by contrast, is a far more mysterious body that could yield more profound discoveries. Its dark surface (Ceres reflects just one-fourth as much light as Vesta) indicates a water-rich interior; some researchers even speculate that it could have a mile-deep ocean under a frozen surface. Water raises the possibility of life, which automatically elevates asteroids in the cosmic pecking order. It also implies that Ceres is the largest intact piece of the raw material that built Earth into the wet, living world it is today. But without close-up observations, these ideas remain hypothetical.
Appendix E: Questionnaire for Experimental Text #2

A. Summary:

*Please summarize the events from the reading:*

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PLEASE TURN PAPER OVER AND ANSWER THE MULTIPLE CHOICE QUESTIONS
B. Questions:

1. What is the name of the probe?
   a. Ceres  
   b. Vesta  
   c. Dawn

2. How long will the probe be in orbit before departing for the largest asteroid?
   a. 9 months  
   b. 10 months  
   c. 11 months

3. What kept the material in the asteroid belt from forming another planet?
   a. A lack of mass  
   b. Too much mass  
   c. Gravity

4. Which asteroid was discovered first?
   a. Vesta  
   b. Ceres  
   c. Dawn

5. What is Vesta’s core made of?
   a. Nickel-iron  
   b. Nickel-cadmium  
   c. Nickel-copper

6. What increases the probability that life exists on one of the asteroids?
   a. A planetlike core  
   b. A basaltic surface
   b. The presence of water

7. What percentage of Vesta was carved out in the massive collision?
   a. 1%  
   b. 3%  
   c. 33%
Appendix F: Background Questionnaire

1. How many hours do you sleep each night?

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2. How old are you? _______

3. Are you…
   a. male
   b. female

4. Are you employed?
   a. Yes, part-time
   b. Yes, full-time
   c. No, I am not

5. What is you major?

6. Are you a freshman/sophomore/junior/senior?

7. Rate your stress level per day (1=no stress; 5=high stress)

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8. How much time do you spend reading on average per week? __________ hrs

9. What is your current GPA? ____________
10. Rank the texts according to what you read most (1=read the least; 6=read the most)

___ a. Textbook related to your major
___ b. Fictional books
___ c. Non-fictional books
___ d. Periodicals
___ e. Internet texts (E.g. news sites, e-mail, blogs, etc.)
___ f. Newspapers
Table 1

*Mean (and Standard Deviation) Number Correct Answers on Probed Recall Task as a Function of Sleep Deprivation and Time Limit*

<table>
<thead>
<tr>
<th>Sleep Deprivation</th>
<th>Time Limit</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>With Time Limit</td>
<td>Without Time Limit</td>
</tr>
<tr>
<td>Sleep Deprived</td>
<td>3.63 (1.31)</td>
<td>3.58 (1.06)</td>
</tr>
<tr>
<td>Not Sleep Deprived</td>
<td>4.59 (1.39)</td>
<td>4.44 (1.12)</td>
</tr>
</tbody>
</table>